Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Proceedings Series 2015/052

Pacific Region

Proceedings of the Pacific regional peer review on the evaluation of soft-shell data for legal-sized male Dungeness Crabs (*Metacarcinus magister*) in Crab Management Areas E, G, and H in British Columbia, 2009-2013

April 21-22, 2015
Nanaimo, British Columbia

Chairperson and Editor: Janet Lochead

Fisheries and Oceans Canada
Science Branch
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

December 2015

Canada

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

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ISSN 1701-1280

Correct citation for this publication:

DFO. 2015. Proceedings of the Pacific regional peer review on the evaluation of soft-shell data for legal-sized male Dungeness Crabs (*Metacarcinus magister*) in Crab Management Areas E, G, and H in British Columbia, 2009-2013; April 21-22, 2015. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2015/052.

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on April 21 and 22, 2015 at the Pacific Biological Station in Nanaimo, B.C. The working paper which focused on an evaluation of soft-shell data for legal-sized male Dungeness Crabs (*Metacarcinus magister*) in Crab Management Areas E, G, and H in British Columbia was presented for peer review.

In-person and web-based participation included Fisheries and Oceans Canada (DFO) Science and Ecosystem and Fisheries Management Sectors staff; and external participants from First Nations organizations, the commercial fishing sector, the Province of British Columbia, service providers, and academia.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report providing advice to Fisheries Management Branch to inform potential fisheries management measures.

The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

Compte rendu de l'examen par les pairs de la région du Pacifique sur l'évaluation des données sur la carapace molle des crabes dormeurs (*Metacarcinus magister*) mâles de taille réglementaire dans les zones de gestion du crabe E, G et H en Colombie-Britannique, de 2009 à 2013.

SOMMAIRE

Le présent compte rendu résume l'essentiel des discussions et conclusions de la réunion régionale d'examen par des pairs de Pêches et Océans Canada (MPO) et du Secrétariat canadien de consultation scientifique (SCCS) qui s'est tenue les 21 et 22 avril 2015 à la Station biologique du Pacifique de Nanaimo, en Colombie-Britannique. Le document de travail qui portait sur une évaluation des données sur la carapace molle des crabes dormeurs (*Metacarcinus magister*) mâles de taille réglementaire dans les zones de gestion du crabe E, G et H en Colombie-Britannique a été présenté aux fins d'examen par les pairs.

Au nombre des participants en personne ou par conférence Web il y avait des représentants des secteurs des Sciences et de la Gestion des écosystèmes et des pêches du MPO, ainsi que des participants externes d'organisations des Premières Nations, du secteur de la pêche commerciale, de la province de la Colombie-Britannique, des fournisseurs de services et des universités.

Les conclusions et avis découlant de cet examen seront présentés sous la forme d'un avis scientifique à l'intention de la Direction générale de la gestion des pêches afin d'orienter la prise de mesures potentielles de gestion des pêches.

L'avis scientifique et le document de recherche à l'appui seront rendus publics sur le site Web du calendrier des avis scientifiques du Secrétariat canadien de consultation scientifique (SCCS).

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on April 21 and 22, 2015, at the Pacific Biological Station in Nanaimo to review an evaluation of soft-shell data for legal-sized male Dungeness Crabs (*Metacarcinus magister*) in Crab Management Areas E, G, and H in British Columbia (B.C.), 2009-2013.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from Fisheries Management Branch. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from First Nations, the commercial fishing sector, the Province of B.C., service providers, and academia.

The following working paper (WP) was prepared and made available to meeting participants prior to the meeting:

> Evaluation of soft-shell data for legal-sized male Dungeness Crabs (*Metacarcinus magister*) in Crab Management Areas E, G, and H in British Columbia, 2009 – 2013 by Brenda Waddell, Jason Dunham, Zane Zhang and Ian Perry (CSAP WP2014INV01).

The meeting Chair, Janet Lochead, welcomed participants, reviewed the role of CSAS in the provision of peer-reviewed advice, and gave a general overview of the CSAS process. The Chair discussed the role of participants, the purpose of the various RPR publications (Science Advisory Report, Proceedings and Research Document), and the definition and process around achieving consensus decisions and advice. Everyone was invited to participate fully in the discussion and to contribute knowledge to the process, with the goal of delivering scientifically defensible conclusions and advice. It was confirmed with participants that all had received copies of the Terms of Reference, working papers, and formal reviews.

The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting, highlighting the objectives and identifying the Rapporteur for each review. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. The room was equipped with microphones to allow remote participation by web-based attendees, and in-person attendees were reminded to address comments and questions so they could be heard by those online.

Members were reminded that everyone at the meeting had equal standing as participants and they were expected to contribute to the review process if they had information or questions relevant to the paper being discussed. In total, 26 people participated in the RPR (Appendix D). Elise Keppel was identified as the Rapporteur for the meeting.

Participants were informed that Dr. Dan Curtis and PhD candidate Joel Harding had been asked before the meeting to provide detailed written reviews for the working paper. Participants were provided with copies of these written reviews.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR). The SAR and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

REVIEW

Working Paper:	Evaluation of soft-shell data for legal-sized male Dungeness Crabs (*Metacarcinus magister*) in Crab Management Areas E, G, and H in British Columbia, 2009 – 2013 by Brenda Waddell, Jason Dunham, Zane Zhang and Ian Perry. WP2014INV01
Rapporteur:	Elise Keppel
Presenter(s):	Brenda Waddell, Jason Dunham and Zane Zhang

PRESENTATION OF WORKING PAPER

Authors Jason Dunham, Brenda Waddell and Zane Zhang each presented a section of the working paper, the abstract of which is included in Appendix E. Brenda Waddell welcomed participants and introduced the authors. Jason Dunham presented an overview of crab biology including the molting process, the development of the monitoring program, and the methods for biological data collection. Brenda Waddell then presented the data analysis methods for the observed data. Zane Zhang presented the two Bayesian models used in the analyses. Then Brenda presented the results by Crab Management Area (CMA), and year, and discussed the uncertainties and recommendations.

POINTS FOR CLARIFICATION

Following the presentation, some participants had points for clarification which the authors addressed.

It was asked whether the sampling program was specifically designed to address the soft-shell question. The authors responded that it was designed in 2009 to address the main research question of when crabs are in soft-shell condition (not abundance or biomass). Index areas were established to increase sampling efficiency. Prior to index areas, service providers had difficulties finding fishing vessels. The establishment of index areas was intended to decrease search time for service providers. The size of each index area was determined based on the need for service providers to minimize search time, while still allowing the catch from a suitable number of vessels to be sampled. The authors noted that the sampling program design was a combination of fixed station and random sampling.

It was questioned why a reduction to 90% of the peak proportion/abundance was chosen? It was asked whether there is any biological or managerial rationale for using this level? The authors responded that the time periods represented by 90% seemed reasonable. The greater the reduction, the longer the period. It was arbitrarily chosen as an example value. It was noted that other reduction estimates can be easily generated.

WRITTEN REVIEWS

In advance of the meeting, written reviews were solicited from two individuals who are knowledgeable in the subject matter: Dr. Dan Curtis (DFO Research Biologist in the Marine Ecosystems and Aquaculture Division) and Joel Harding (PhD candidate, Simon Fraser University). Both reviewers felt the paper was well written and that it met the objectives outlined in the Terms of Reference. Discussions regarding editorial issues and clarification of model details took place. Larger issues requiring further vetting were deferred to General Discussion. The full reviews are given in Appendix B.

GENERAL DISCUSSION

The participants identified key issues for group discussion. A brief synopsis of these issues as discussed by the reviewers, authors, and participants follows.

Concerns were raised regarding some editorial issues in the paper. To address these issues the authors agreed to use consistent terminology and to present the data for each CMA in a consistent manner to improve the flow. Further editorial improvements and streamlining of the paper's structure will be accomplished with the assistance and advice of Dr. Dan Curtis.

It was questioned why only the legal-sized soft-shell male data were analysed, which led to questions around what the study was trying to inform. Did the Fisheries Managers' questions originate from a biological or an economic perspective? The authors acknowledged the merit of looking at the data more comprehensively (i.e., consider also females and sublegal males) in the future, but in the working paper they wanted to establish the methodology for analyzing soft-shell data. It was recognized that direction for future work would have to come from a higher level framework document, for example. The authors agreed to make a statement about restriction of focus of the paper.

A participant asked why only threshold values of 85%, 90% and 95% were presented. The authors stated that they were simply providing a number of arbitrary but practical reductions without bias regarding what levels managers might choose. It was recommended that the authors include the larger reductions of 50 and 75%, and the authors agreed.

Discussions took place around the way in which catch per unit effort CPUE was calculated; including why traps with very short and very long soak times were excluded along with a suggestion to divide by total trap time instead of number of traps. The authors indicated that most soak times fell between 21 and 24 hours, so the exclusions made very little difference. The participants agreed that trap assessments with crustaceans using a target soak time of 24 hours is an accepted means, and that 24 hours, give or take, rolled up into one sampling event is consistent with accepted practice. Therefore, it was agreed that no changes to the CPUE calculation would be required.

An Industry representative raised some concerns regarding the fishery-independent sampling program, highlighting that there are many variables that will affect trap catches such as interaction among crabs in a trap, location of a trap, soak time, and experience level of the sampler. The authors indicated that this sampling program was initiated to ensure sufficient sample sizes of crabs were collected during each sampling event. This was achieved by establishing index areas. Concerns were raised regarding whether the index areas chosen represent the populations. The authors explained that fixed station designs are very common and accepted methods of sampling, and that by repeatedly sampling the same locations over time, sampling variability is decreased by removing between site variability. Furthermore, a sampling program that follows the commercial fleet instead of repeatedly sampling in the same areas might not produce better results in terms of identifying soft-shell timing. If commercial harvesters try to avoid soft crabs, then crabs sampled would not accurately represent the true soft-shell condition in the crab population. It was noted that the fishery-independent sampling seemed to reflect the fishery-dependent sampling; overall the results between the two sampling programs were similar.

Concerns over how removing hard-shelled crabs and leaving the soft-shelled crabs may affect the proportion of soft-shell crabs in the population were discussed. It was concluded that it would be difficult to quantify this effect, but this issue was noted as an uncertainty.

The authors were open to suggestions on ways to improve the model and agreed to add rationale for using days and days^2 in the methods, add the formulae for calculating the pseudo

R^2, and to present goodness of fit (R^2) within text. The authors agreed to try out a quasi-binomial distribution model as well as a random effect in the model structure. The authors also agreed to rerun the model with a reviewer's suggested changes around number and length of chains to see if convergence strengthened and certainty of posterior estimates increased. Furthermore, a participant felt that model uncertainty was not adequately mentioned in the working paper and the authors agreed to add statements addressing this in the Discussion.

Gaps in the data, particularly in the fishery-dependent sampling, were also flagged as a concern. Sampling frequency was lower in the fishery-dependent sampling program, and gaps between sampling events during late fall and winter months may have affected the model's ability to produce biologically meaningful outputs. Increased sampling frequency would improve accuracy of the estimation of soft-shell timing for the population. The participants felt that statements regarding peak soft shell times were worded too strongly considering the gaps in the data and the authors agreed to change wording to more accurately reflect support from the data.

The results indicate a summer soft-shell peak in 2009. The participants questioned whether this was a real peak, and not an artifact of missing data. It was asked whether the additional data in the early part of the rest of the years drive the numbers down, and whether the lack of data from October to December 2008 possibly caused an artificial summer peak in 2009. Upon further examination, it was noted that the summer peak in 2009 was supported by the observed data, and therefore it was not an artifact.

The participants felt that the Discussion could be improved by providing broader context, including how environmental variables can affect moult timing and the science behind the management measures used in other areas included Alaska and Washington; the authors agreed.

The objectives outlined in the Terms of Reference were fully achieved.

CONSENSUS ON PAPER ACCEPTABILITY

During the development of consensus on the paper's acceptability Industry remained concerned about the use of index areas and the many variables that would have affected catch in the fishery-independent sampling program. The participants noted that the use of index areas and fishery-independent sampling is widespread and that these are accepted methods of sampling. It was highlighted that the authors effectively identified soft-shell timing based on the results of the study, regardless of the caveats associated with the sampling design. There was consensus on the analysis and results, and therefore the working paper was accepted with the agreed upon revisions.

CONCLUSIONS & ADVICE

- Although legal-sized male Dungeness Crabs were observed in soft-shell condition at almost any time of the year, the estimated peak in proportion and relative abundance of soft crabs generally occurred in March.
- High numbers of soft-shell legal-sized male crabs were observed in other seasons, for example, in 2009, a secondary summer peak was observed in 5 of the 8 index areas.
- Fishery-independent and fishery-dependent sampling programs showed similar observed trends in peak timing of soft-shell legal-sized males.
- Results derived from fishery-independent proportion method may better describe when legal-sized male Dungeness Crabs are in soft-shell condition.

- Results derived from the fishery-dependent CPUE method best describe when the commercial fleet catches high numbers of soft-shell legal-sized male crabs.
- The proportion model produced longer estimated soft-shell periods, more precise start/end dates and peak dates, and had a higher degree of certainty in model predictions than the CPUE model.
- Results are summarized in tables providing the 95% credible intervals for peak soft-shell dates and start/end dates of the soft-shell period as defined by a range of reduction levels (0.50 to 0.95 of the peak value) for each Crab Management Area for both proportion and relative abundance models.
- Further research to understand environmental determinants of the observed interannual variability in Dungeness Crab soft-shell periods in BC may reduce uncertainty around estimates.
- Biological sampling programs, designed to determine crab soft-shell periods with high certainty, require consistent and frequent sampling of sufficient numbers of crabs throughout the year to produce meaningful results.
- The identification of measurable population health and sustainability objectives is required in order to inform future research that will quantitatively determine the efficacy of potential management measures.

ACKNOWLEDGEMENTS

Dr. Dan Curtis (DFO Research Biologist in the Marine Ecosystems and Aquaculture Division) and Joel Harding (PhD candidate, Simon Fraser University) each provided a thorough written review of the working paper. Their efforts in providing this feedback to the committee and authors are greatly appreciated. Also the committee greatly appreciated Elise Keppel acting as rapporteur for the meeting.

APPENDIX A: TERMS OF REFERENCE

Evaluation of soft shell data for legal-sized male Dungeness Crab (*Metacarcinus magister*) in Crab Management Areas E, G, and H in British Columbia, 2009-2013

Regional Peer Review Process – Pacific Region

April 21-22, 2015
Nanaimo, British Columbia

Chairperson: Janet Lochead

Context

Commercial fishing for Dungeness Crab (*Metacarcinus magister*) occurs throughout British Columbia's (BC's) coastal waters. The fishery is managed under a precautionary regime that includes a minimum harvestable size limit, sex restriction, limited commercial licensing, area licensing, trap limits, soak limits, and gear restrictions. Additionally, in some areas of the coast, fishing closures or trap haul restrictions have been implemented to protect male crabs from handling injury and mortality during the vulnerable soft shell stage following moulting.

Three of seven Crab Management Areas (CMAs) in BC (Areas I and J, Fraser River area; and Area A, Hecate Strait/McIntyre Bay) have seasonal closures to protect large male crabs while in soft shell condition. Seasonal closures are set in the Crab-By-Trap Integrated Fisheries Management Plan (IFMP), although in CMA A there is a soft shell sampling program paid for by Industry. Information from this program is used by fisheries managers and Industry to better understand variability in soft shell timing and to potentially adjust fishing season opening and closing times.

Four CMAs in BC (B, E, G, H) are currently not managed using seasonal soft shell closures as the timing in these areas is largely unknown. In 2009, the Industry-sponsored Dungeness Crab biological sampling program was expanded in CMAs E, G, and H to collect fishery-independent and dependent crab biological data monthly to identify soft shell timing of legal-sized crabs. Data were collected in CMAs E, G and H from 2009 to 2013 (5 years). No such expanded sampling program was implemented in CMA B. After consultations with DFO, Industry, and Service Providers, the crab biological sampling program was improved to incorporate a long-term vision of departmental data requirements other than soft shell timing and to reduce costs to Industry. The modified sampling program, which still requires both fishery-independent and dependent sampling, was implemented in 2013 in Area B and 2014 in Areas E, G, and H and may remain a condition of license for years to come.

DFO Fisheries Management Branch has requested that Science Branch provide an analysis of crab biological data collected in 2009 - 2013 from the expanded sampling program to evaluate the timing and magnitude of soft shell occurrence in legal male crabs in CMAs E, G, and H. The assessment and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) will be used to inform the management of commercial crab fisheries.

Objectives

The following working paper will be reviewed and provide the basis for discussion and advice on the specific objectives outlined below.

Waddell, B, J.S. Dunham, Z. Zhang and I. Perry. 2015. Evaluation of soft shell data for legal-sized male Dungeness Crab (Metacarcinus magister) in Crab Management Areas E, G and H in British Columbia, 2009-2013. CSAP Working Paper 2014INV001.

1. Provide estimates of proportions and catch per unit effort (CPUE) of soft shell legal males from commercial vessel and standardized fishery-independent sampling programs in CMA's E, G, and H from 2009 to 2013.
2. Fit statistical models to the sample data to determine population estimates of proportion and relative abundance of soft legal male crabs, including estimates of uncertainty.
3. In the form of decision tables, provide population estimates and timing of peak soft shell proportion and relative abundance.
4. Discuss sources of uncertainty of this assessment, including the sampling program and data limitations.

Expected Publications

- CSAS Science Advisory Report
- CSAS Research Document
- CSAS Proceedings

Participation

- Fisheries and Oceans Canada (DFO) MEAD, FAM
- First Nations with traditional territories in Areas E, G, H
- Industry commercial crab fishery area reps (in particular Areas E, G, H)
- Service Providers (Pacific Coast Fisheries Services (PCFS) and Ecotrust) responsible for collecting crab biological data
- Conservation and Protection Branch
- Sport Fish Advisory Board (SFAB)
- Marine Fisheries Management, Province of BC

APPENDIX B: WORKING PAPER REVIEWS

DAN CURTIS' REVIEW

Fisheries and Oceans Canada

Canadian Science Advisory Secretariat (CSAS)

Regional Peer Review Process - Pacific

Written Review

Date: April. 8, 2015

Reviewer: Daniel L. Curtis, Fisheries and Oceans Canada

CSAS Working Paper: 2014INV01

Working Paper Title: *Evaluation of soft shell data for legal-sized male Dungeness Crab (Metacarcinus magister) in Crab Management Areas E, G and H in British Columbia, 2009-2013*

Overall Comments:

The authors present valuable observational data and estimations on the timing of the Dungeness Crab softshell period for Crab Management Areas (CMA) E, G, and H (West Coast Vancouver Island, Johnstone Strait, and the Strait of Georgia, respectively). The results of this study provide managers with various arbitrary scenarios of reductions in proportion and abundance from an estimated peak that should allow decisions to be made for fisheries closures in each of these areas depending on management objectives. Although I would caution that until a much longer data set can be collected to account for the high degree of variability in the timing and duration of the annual spring moult period, any management actions should be accompanied by a sampling program to determine the timing for in-season closures, as occurs in CMA A. While the scope of this research document is somewhat limited to the contents of the associated TOR and RSIA, the large amount of data other than just on legal male crabs generated from this sampling program is extremely valuable and could be used to answer much broader questions about the biology of Dungeness Crabs in these CMAs.

Meeting Specific Objectives:

The authors have done a satisfactory job of meeting the objectives of this working paper using the data that were available. I have provided a general overview for each specific objective here, more detailed comments are provided below.

1. Provide estimates of proportions and catch per unit effort (CPUE) of soft shell legal males from commercial vessel and standardized fishery-independent sampling programs in CMA's E, G, and H from 2009 to 2013.

The authors provide estimates of commercial vessel and standardized fishery-independent sampling programs in CMA's E, G, and H. While the authors make the most of the data at hand, the results would have greatly benefitted from an increased number of sampling events, particularly for the commercial vessel data.

2. Fit statistical models to the sample data to determine population estimates of proportion and relative abundance of soft legal male crabs, including estimates of uncertainty.

Although I am not particularly well equipped to judge the efficacy and fine details of the models used to estimate the proportion and relative abundance of soft legal male crabs, I feel that the results generated meet this objective and that empirically, the model results seem reasonable.

3. In the form of decision tables, provide population estimates and timing of peak soft shell proportion and relative abundance.

Decision tables are provided (Tables 6-18) with reductions from estimated peak abundance or proportion based on model results. Although these tables do not fit the classic decision table model (ie. If criteria a, b, and c are met, management action y should be carried out), they do provide a basis and rationale for management actions. Given the short time series of data used to generate the models, and the high degree of variability in the data, it would be wise to exercise caution when applying these results to management actions.

4. Discuss sources of uncertainty of this assessment, including the sampling program and data limitations

The authors dedicate a substantial portion of the discussion to sources of uncertainty in this study and identify defining 'soft shell', interannual variability, and missed sampling events as key sources. I agree with each of these points, but would also add that sampling program may have led to variability in the data and that more weight needs to be given to the influence that fishing location within a CMA or even within an index area, as well as the experience level of the fishers in the SFI sampling program. Further discussion is also warranted on the uncertainties surrounding the differences in how the gear was fished between the SFI and FD programs and how this may have affected the results of the observed and modelled data.

Specific Comments:

1. Presentation of the data

I commend the authors for their presentation of what is a large amount of somewhat unwieldy time series data. Coherently presenting data from multiple sites, over multiple years, from multiple sampling programs is never easy. While I appreciate that the nature of a CSAS Research Document affords the luxury of presenting large amounts of data, I feel that the clarity of the results presented would benefit from a re-organization and/or stream lining of the data presented. It would also be helpful if consistent formatting, titles, and axis labels were used for the figures and tables. The same information is often presented in re-organized forms in multiple tables and figures. It may be possible to either merge or remove some of the tables that duplicate content of other figures and tables. Consistent presentation of the data for each CMA would also help the reader make comparisons.

Using CMA H as an example: For figure 10 present the pooled proportion data for the entire CMA, broken down by sampling program, as a single panel and include the SE. The way it is currently broken down makes seasonal trends and differences between the sampling programs hard to interpret. This is the data that was used to generate the model results presented in figure 11, and will make interpreting the model results easier. Do the same for the CPUE data. Following that, present either the current figure 10 or appendix figure 1 (they present the same data) and use it to discuss the differences between Index areas (3.2.6). Do the same for the CPUE data.

To summarize, for each section the figures would go: Proportion data summary CMA level, proportion model results CMA level, CPUE data summary CMA level, CPUE model results CMA level, Proportion data Index site level, CPUE data Index site level.

Although justification for separating Sooke and Tofino are given, it may be helpful for consistencies sake to present summary results for all of CMA E.

2. Sampling

Spatial Issues: much of the variability in CPUE between years and temporally close sampling events may be the result of spatial issues. While in the FD sampling program it is difficult to

control where the sets were, it is unclear whether or not the sets for the SFI program were repeated at the same stations. As anyone who has fished Dungeness can attest, moving a string of traps 500 m one way or another or a little bit deeper or shallower can have drastic effects on catch rate. These are issues that are clearly addressed in Dunham et al. (2011). Since the data have already been collected it is important to address how site selection may have affected the outcomes. The authors indicate that index sites were chosen based on previous catch records. However, estimates for soft shell timing based on these limited number of index sites may not be reflective of the entire CMA since the commercial fishery tends to focus on areas of high productivity. The index sites are likely more similar to each other than they are reflective of the entire CMA.

Differences in the sampling programs: factors such as soak time may have drastic effects on the proportion of different classes of crabs in a trap (female, sub-legal males, soft, etc.). It would be helpful if the authors could clarify how these factors may have affected the observed CPUE and proportion data, and in turn the model outcomes for each of the sampling programs. For example, if a large old shell male is the first crab in a trap, the probability of getting legal soft males in the trap is going to be lower than if the first crab in the trap is a sub legal or legal soft male. Since trap efficiency declines drastically after the first 12h, that trap would then essentially be stuck with a low proportion of soft males. Factors such as these may account for some of the differences between the SFI and FD programs since the FD program would have been targeting hard legal males. Also, instances of cannibalism increase with soak time and these events are likely not always evident when the trap is hauled to the surface. These unfortunately are the caveats of any trap survey, regardless of design, but they do warrant some further attention in the discussion.

Although in most cases the data used provided significant model fits, it is rather sparse in many cases (especially for the FD data) and likely resulted in the low R^2 values seen for some of the model runs. The authors do a good job of highlighting this caveat. Continued sampling is likely necessary to improve the precision of these results and overcome the high degree of interannual variability seen in the observational data. As mentioned above, modelling is not my area of expertise, but it should be possible to set a desired level of precision and use this to determine how much further sampling is required to meet that level.

3. Use of only legal male data

Many Dungeness crab fisheries are managed by essentially removing most of the legal male crabs from the population annually. Since the crabs are sexually mature for 1-2 years prior to becoming legal, a viable population is maintained. It can therefore be argued that from an ecological perspective, the maintenance of a healthy population is more dependent on the population of female crabs and sub-legal adult males. While the analysis of this data is not addressed in the specific objectives, the authors indicate that it was recorded for at least the SFI sampling program. Including information on when the highest CPUE of soft sub-legal males and females was may provide more valuable insight into optimal timing for a soft shell closure than the data on soft legal males.

4. Increased context for the discussion

The discussion section would benefit from increased context as to how fisheries in other areas (both within and outside of BC) are managed with regards to the soft shell period and the justifications, science, and monitoring programs that are used as the basis for these management actions. From a science, not a regulatory perspective, how might these be improved upon or modified to suit the needs for CMAs E, G, and H?

JOEL HARDING'S REVIEW

Fisheries and Oceans Canada

Canadian Science Advisory Secretariat (CSAS)

Regional Peer Review Process - Pacific

Written Review

Date: April. 8, 2015

Reviewer: Joel Harding, Simon Fraser University

CSAS Working Paper: 2014INV01

Working Paper Title: *Evaluation of soft shell data for legal-sized male Dungeness Crab (Metacarcinus magister) in Crab Management Areas E, G and H in British Columbia, 2009-2013*

Overall Comments:

The authors have done a very good job analyzing and presenting a very large and complex data set that encompasses multiple methodologies across substantial spatial and temporal scales. They have successfully summarized peak soft shell periods and relative abundance for sampled populations of legal-sized male Dungeness crabs although there are some issues with the methodology needing clarification or revision. The objective of the paper also remains a bit unclear to me in terms of what this study is attempting to inform (ie. conservation, precautionary management, or market-driven fishery closures). I like the Bayesian approach used in analyses although the uncertainty around the model posterior estimates is not presented clearly enough nor discussed adequately in the paper. I also believe the use of a quasibinomial family in models would properly account for dispersion in the raw data and generate appropriate credible intervals. I have provided a list of major concerns listed below along with minor comments/ edits which are tracked in the attached document. I will likely not make the CSAP meeting later this month but I am happy to respond to any questions or concerns with the review.

1. Major Concerns:

The main objective of this working paper is unclear. Is the purpose to protect only legal-sized males in soft shell condition or all males? There are obviously conservation concerns related to the impacts of commercial fishing on all crabs including females and sub-legal males that should be considered. If the concerns are mainly related to the low market value of soft shell legal males then it should be explicitly stated in the paper so this study is not construed as having conservation objectives. Including sentences like: "While in this soft shell condition, crabs are more vulnerable to being injured and killed as a result of reduced protection from a hardened exoskeleton. To better protect legal-sized male crabs in Crab Management Areas E, G, and H, fisheries managers have requested information regarding the timing and variability when these crabs are soft-shelled." suggests this study is informing precautionary management or conservation of stocks. If this is the case wouldn't the rationale be to protect females and all sizes of males in soft shell condition given the effects of fishing will impact the reproductive capacity of populations (females) and individuals eventually recruiting in to legal sizes (sub-legal males) and thus directly relate to the survival and abundance of legal-sized males? The objective needs to be more clearly defined in the paper.

2. Methodology:

a) Line 21-22: What is the rationale for choosing 95, 90 and 85% threshold values? Are these values actually arbitrarily chosen? They are the three next lower values from 100% by increments of 5, which is quite biased towards low reductions below peak

periods. Would it not be more valid to use three reduction values within a range of values used by existing management strategies (if they exist)? Or three reduction values that cover a broader range (ie., 50, 75 and 90)? These numbers need to be substantiated with some sort of biological underpinning as to why the associated windows would adequately protect crabs during soft shell stages. Please compare to other management programs in place in Alaska Washington and Oregon if comparisons can be made. Providing a short synopsis of what implemented regulations exist will better enable the readers to assess how this study fits into the larger picture.

b) Data checks and exclusions: Including traps with no crabs in analysis is a good idea however I would like to see some additional information regarding locations of traps for SFI sampling. Were there lines set in areas that are known to be poor habitat or that the commercial fleet avoids? If so, there may be reason to exclude them from analysis. Although ease of access is an important consideration to complete data collection, if index areas were placed in areas not commercially fished or areas of poor habitat suitability, this would bias results. Index site suitability should be limited to if the area is commercially fished or some other verification of habitat suitability. In addition, I do not see why SFI traps that soaked longer than 28 hours were excluded, if there isn't any biologically or statistically robust reason to omit then these traps should be included in analyses.

c) CPUE calculation: I can see how dividing by the number of traps works if sampling time is constant across all sampling events. But given that sample time varied among sampling events, dividing by total trap time (sum of soak time of all traps within a sampling event) rather than number of traps would be more reflective of actual CPUE comparisons over space and time. My suggestion would be re-run analyses with total trap time replacing number of traps in the denominator of CPUE calculations.

d) Use of additional predictors in analyses such as water temperature to look at variability in peak soft shell periods. Much of the data looks highly variable between years and I'm wondering if adding some additional parameters would explain that. Could use regional temperature data from weather buoys or some other source.

e) Analyzing individual years for CMA H makes sense. I would suggest doing the same for CMAs E and G for comparison even if data is limited. Authors can suggest discarding from considerations due to data limitations but at least the information is there.

3. **Models:**

a) Describe the rationale for using days and days2 in the methods.

b) Include how R2 was calculated for model fit in methods. Is it a pseudo R2?

c) What is the residual variation of these models? Do they meet assumptions of normality? My guess is there is overdispersion in a lot of the residuals from these analyses warranting use of a quasibinomial family instead of binomial. The CI bands in many of the posterior estimates no not reflect the dispersion of the raw data points. Model uncertainty is a major factor in these analyses that is not yet properly accounted for or discussed.

d) Did the authors conduct any posterior predictive checks? (predicted vs. observed). The paper sort of skips over how well the models performed, R2 are in tables but not mentioned in results and model uncertainty is not mentioned in discussion. This is required to be able to discern which models are performing well and which ones are

performing poorly. Poorly performing models should not necessarily inform management decisions.

e) Would a state-space model perform better in terms of reflecting variability of peak soft shell timing?

f) Page 7- It would be much more simple to use a random effect (or hyper-alpha term) in the model structure to allow intercepts to vary between sampling years (essentially acknowledging that crab abundance may vary by year within an index area). This would allow the authors to use actual CPUE estimates, and avoid the log-log function to simplify interpretation.

g) Page 8: In my limited experience with Bayesian modeling the use of two 20K long chains, with 10K burn-in and 100 thinning interval is pretty skimpy. Why not three 50K long chains with a 25K burn in and 25-50 thinning interval? Wouldn't this potentially strengthen convergence and certainty of posterior estimates?

4. **Results:**

a) Would be good to have a vertical line or something indicating estimated peak date with 95CI in figures 11, 13 etc.

b) Within each section of the results it would be good to present the goodness of fit (R2) in addition to the uncertainty around posterior estimates within the text as I think this will need to be discussed in future sections.

c) Large data gaps in 2011 and 2012 do not support statements that peak soft shell times were similar for all years. These large data gaps need to be recognized more in the results with associated levels of uncertainty around peak timing. Many of the years could have peak, or a second peak timing during the data gaps. Although this is sort of addressed later in the paper, it needs to be fully recognized throughout the results section. The current statements are too strong and not clearly supported.

d) The word 'majority' is used throughout the results as in: "the majority of legal male crabs were soft in the spring for all years". This is not the right word, the majority (as in the largest proportion) of soft shells could have occurred through the summer months in some years. The proper word to use here, and in all similar sections, would be 'peak'; the maximum proportion value within a year.

5. **Discussion:**

a) Model uncertainty is not adequately mentioned and needs to be a major part of the discussion as per previous comments.

b) In the discussion compare and contrast seasonal closures and gear restrictions to in-season restrictions such as those used by Washington State and methods used elsewhere. To me, this analysis could support consideration of in-season management measures given the variability of peak soft shell times in CMA H and would be worth mentioning. Seeing how year-to-year variability compares in the other CMAs would also help.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat
Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Evaluation of soft shell data for legal-sized male Dungeness Crab (Metacarcinus magister) in Crab Management Areas E, G and H in British Columbia, 2009-2013

April 21 and 22, 2014

Pacific Biological Station, Nanaimo, British Columbia

Chair: Janet Lochead

DAY 1 - Tuesday, April 21, 2015

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Authors
1030	***Break***	
1045	Overview of Written Reviews	Chair + Reviewers & Authors
12:00	***Lunch Break***	
1300	Identification of Key Issues for Group Discussion	RPR Participants
1330	Discussion & Resolution of Technical Issues	RPR Participants
1445	***Break***	
1500	Discussion & Resolution of Results & Conclusions	RPR Participants
1630	Adjourn for the Day	

DAY 2 - Wednesday, April 22, 2015

Time	Subject	Presenter
0830	Introductions Review Agenda & Housekeeping Review Status of Day 1	Chair
0845	*(As Necessary)* Carry forward outstanding issues from Day 1	RPR Participants
1000	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1030	***Break***	
1045	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1200	***Lunch Break***	
1300	*Science Advisory Report (SAR)* • Continued	RPR Participants
1445	***Break***	
1500	Next Steps – Chair to review • SAR review/approval process and timelines • Research Dccument & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair
1545	Other Business arising from the review	Chair & Participants
1600	***Adjourn meeting***	

APPENDIX D: PARTICIPANTS

Last Name	First Name	Affiliation
Barney	Amanda	Ecotrust North
Barton	Leslie	DFO Science
Buitendyk	Willem	Pacific Coast Fishery svc
Buitendyk	Hank	Pacific Coast Fishery svc
Campbell	Kelvin	Area H Crab Association
Chalmers	Dennis	Province of BC
Curtis	Dan	DFO Science
Davies	Shaun	DFO Fisheries Management
Dunham	Jason	DFO Science
Duprey	Nick	DFO Science
Edwards	Dan	Area A Crab Association
Gillespie	Graham	DFO Science
Harding	Joel	Simon Fraser University
Hargreaves	Marilyn	DFO Science CSAP
Heggelund	Henry	Area E Crab Association
Heggelund	James	Area E Crab Association
Humble	Sylvia	DFO Fisheries Management
Keppel	Elise	DFO Science
Laliberte	Bernette	Cowichan Tribes
Lochead	Janet	DFO Science
Norgard	Tammy	DFO Science
Perry	Ian	DFO Science
Rusel	Christa	A-Tlegay Fisheries Society
Rutherford	Dennis	DFO Science
Waddell	Brenda	DFO Science
Zhang	Zane	DFO Science

APPENDIX E: ABSTRACT OF WORKING PAPER

Dungeness Crabs (*Metacarcinus magister*) increase in size incrementally by moulting. In southern British Columbia, Canada, legal-sized (large) male crabs are believed to moult generally during the winter and spring, although the specific time is unknown. After moulting, the new shell is soft, and gradually hardens over the next two to three months. While in this soft shell condition, crabs are more vulnerable to being injured and killed. To better protect large male crabs in Crab Management Areas E, G, and H, fisheries managers have requested information regarding the timing and variability when legal-sized male crabs are soft-shelled. As a result, a collaborative research program involving DFO and the crab fishing industry was conducted from 2009 to 2013. Crab biological data were collected in two ways: 1) using standardized trap gear fished independently of the commercial fishery, and 2) from commercial vessels actively fishing. Two analytical methods were used: (1) we examined the proportion of soft shell legal males to all legal male crabs sampled, and (2) we examined the numbers of soft shell legal male crabs collected per trap (CPUE). Bayesian models were developed to estimate the timing of peak proportion and relative abundance of soft crabs based on observed data from the two sampling programs. Modelling also determined time periods (including estimates of uncertainty) when the proportion and relative abundance of soft legal males were 95%, 90%, and 85% of peak values. The highest (peak) proportion and relative abundance from analyses of soft legal male crabs in the three Crab Management Areas ranged from March 5 to 27. Using proportion data from the fishery-independent sampling program, and a 10% reduction from the peak (0.90 × Peak), 43-62% of the legal male crabs were soft on any given day starting January 15-February 5 and ending May 7-16.